Evolutionary Models of Irregular Warfare

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The objective of this research project was to conduct a preliminary study exploring the utility of evolutionary models of irregular warfare (e.g. in Iraq and Afghanistan). The approach was to apply analytical tools developed in evolutionary biology to understand how insurgent and terrorist populations change and adapt over time. These tools have not been used before for this purpose. However, evolutionary models offer promising insights for irregular warfare because they focus explicitly on key processes that are essential to understand and predict how interacting populations in competition with each other grow, survive, adapt, and ultimately die out. A key output of the study has been to help establish the Natural Security Project, a collaboration among marine biologist Rafe Sagarin, former UN weapons inspector Terry Taylor, and the PI Prof Dominic Johnson. The project seeks to explore if and how we can derive insights from nature to help tackle problems of international security in the 21st century. So far, we have focused on the pressing problems of operational adaptation. However, our current and future work extends evolutionary principles to the level of grand strategy and international politics. This has given rise to some unexpected results: for example, work from our group explored evolutionary lessons for when and how we should transmit signals to other actors, and the conditions under which actors that overestimate their capabilities may out-compete unbiased ones.

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CONTENTS

Background to the Project

This project is developing three new ideas that may be important to our understanding of modern irregular warfare.

The first idea is to explore **evolutionary theory as a framework to understand new security threats**, and for insights about how to improve our ability to respond to them. The rationale for this is that many security threats of the 21st century, while diverse, share common features: they are novel, rapidly changing, and require flexible, adaptive responses. Evolutionary theory offers well-established theoretical and empirical tools for analyzing the process of adaptation, and these can be applied to any system of interacting entities, whether animals, humans, or organizations. I and colleagues have laid out the arguments for this overall approach in recent publications (see Johnson 2012 in the Appendix for a recent overview).[1]

The second, more specific idea within this overall evolutionary framework is to use **ecological population models to study how insurgencies and terrorist groups grow, change and decline over time**. The rationale for this is that population models developed in ecology offer a way of quantifying, analyzing, and making predictions about current and future population sizes, such as the sizes of insurgent forces, while only needing a small number of parameters to do so. Furthermore, they allow one to explore the effect of alternative strategies—whether, and how much, alterations in key parameters are likely to increase or decrease the target population size over time.

The third area of work is understanding **the process of military adaptation**. Our initial research suggests that, counter-intuitively, weaker sides in asymmetric conflicts may enjoy better and faster adaptation, because they are: (a) more varied; (b) under stronger selection pressure; and (c) freer to replicate successful strategies. These are the three conditions for effective

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[1] Johnson, D.D.P. and Madin, E.M.P. (2008a) Paradigm Shifts in Security Strategy: Why Does it Take Disasters to Trigger Change? In: Sagarin, R.D. and Taylor, T., editors. *Natural Security: A Darwinian Approach to a Dangerous World*. University of California Press, Berkeley and Los Angeles, CA, pp. 209-239.

Sagarin, R., Alcorta, C., Atran, S., Blumstein, D., Dietl, G., Hochberg, M., Johnson, D.D.P., Levin, S., Madin, E., Madin, J., Prescott, E., Sosis, R., Taylor, T., Tooby, J., and Vermeij, G. (2010) Decentralize, adapt and cooperate. *Nature* 465:292-293.

Sagarin, R. (2012) *Learning From the Octopus: How Secrets from Nature Can Help Us Fight Terrorist Attacks, Natural Disasters, and Disease*. Basic Books, New York.

adaptation under Darwinian selection. In irregular warfare, selection effects may thus favor insurgents or terrorists, leveling the playing field even against opponents with significantly stronger military power.[2]

The remainder of this report focuses on the second aspect: developing population models to understand and predict how insurgent population sizes grow, change, and decline over time. This has been the primary focus of the current grant effort. The big question is whether we can apply these models to the current war in Afghanistan, and what insights it may generate.

Logistic Models of Insurgency

Our initial work on insurgency applied logistic models to two conflicts: (1) Iraq from 2003-2006; and (2) the entirety of the Malaya Emergency from 1948-1960. [3] The latter, though not of contemporary significance, was important because it allowed us to test whether the models accurately reflected the historical data. In other words, it provided a way of validating the approach (models fitted to data from the *first half* of the Malaya insurgency were successful in generating insights about the second half, and the final decline of the insurgency). The current project first seeks to highlight differences between quantitative and qualitative insights of these models. Ideally, population models would give us point predictions for how large an insurgency will be at some given time in the future, or how it might increase or decline if we apply alternative strategies. In reality, models do not always generate high levels of accuracy, or even unique predictions. But we can nevertheless explore what the predictions are, and test these predictions against what happens as history unfolds. Here we illustrate the approach with the insurgencies in Iraq and Malaya, where we did generate specific quantitative predictions for the size of the insurgency in future years.

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[2] Johnson, D.D.P. (2009) Darwinian selection in asymmetric warfare: the natural advantage of insurgents and terrorists. *Journal of the Washington Academy of Sciences* 95:89-112.

[3] Johnson, D.D.P. and Madin, J.S. (2008b) Population models and counterinsurgency strategies. In: Sagarin, R. and Taylor, T., editors. *Natural Security: A Darwinian Approach to a Dangerous World*. University of California Press, Berkeley and Los Angeles, CA, pp. 159-185.

Quantitative Insights for Malaya

In Malaya (Figure 1), logistic models tracked the historical data relatively well. In particular, it predicted a negative recruitment rate in the latter years of the war (Figure 1, top panel). Under normal circumstances, a negative recruitment rate might be rather strange. However, in the case of the Malaya insurgency, the recruitment rate may well have really become negative because the British began paying insurgents to come out of the jungle, and paid them more if they went back to bring out comrades. A second feature was a stark change in the course of the war after year 4. This appeared to correspond with the historical change to a full military counter-insurgency strategy at that point. These matches of model to history offered some confidence in the broad representativeness of the model.
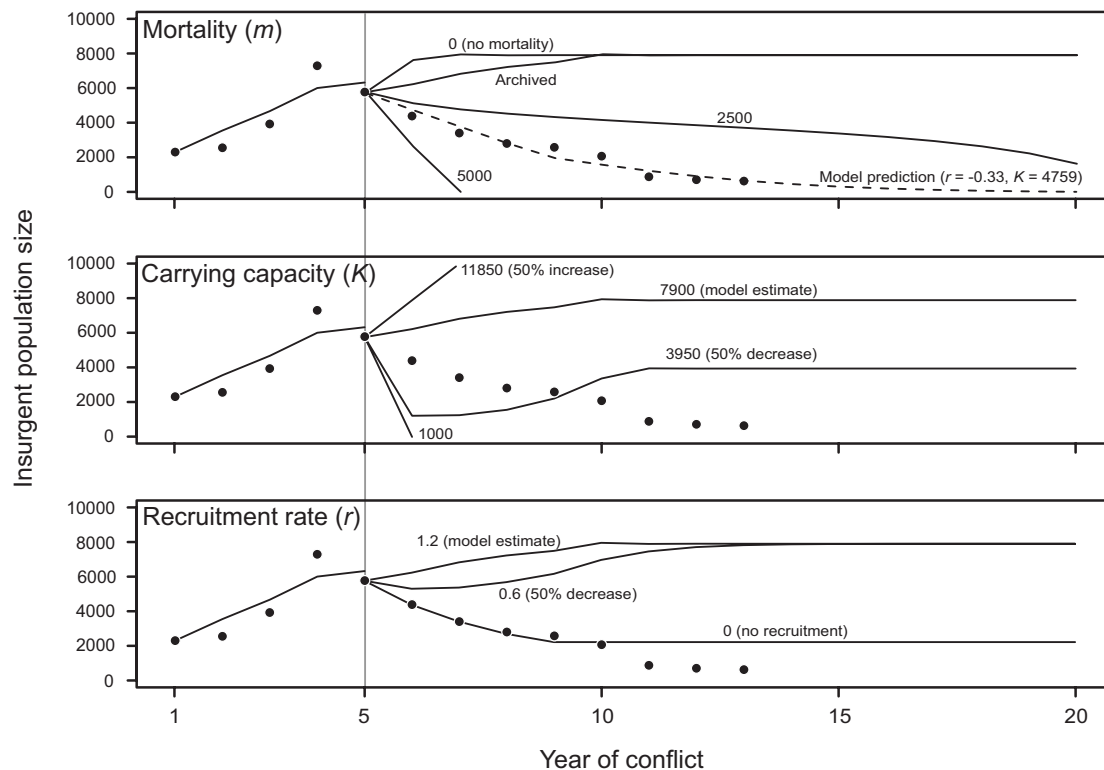

Figure 1. *Logistic models (black lines) fitted to historical data (black dots) on the size of the insurgency in Malaya, 1948-1960. Multiple lines after year 5 show model predictions under alternative parameter values (one parameter per panel, in which all other parameters are held constant).*

Quantitative Insights for Iraq

In Iraq, we only modeled the data up until the bombing of the al-Askari mosque in February 2006 (because after this point, the war was generally thought to become a civil war, rather than a two-sided insurgency). As a result, predictions from the model must be examined with the caution that they were generated in a rather different phase of the war. Nevertheless, the predictions did offer some broad brush ideas about how long the campaign might last given changes in key parameters (Figure 2).
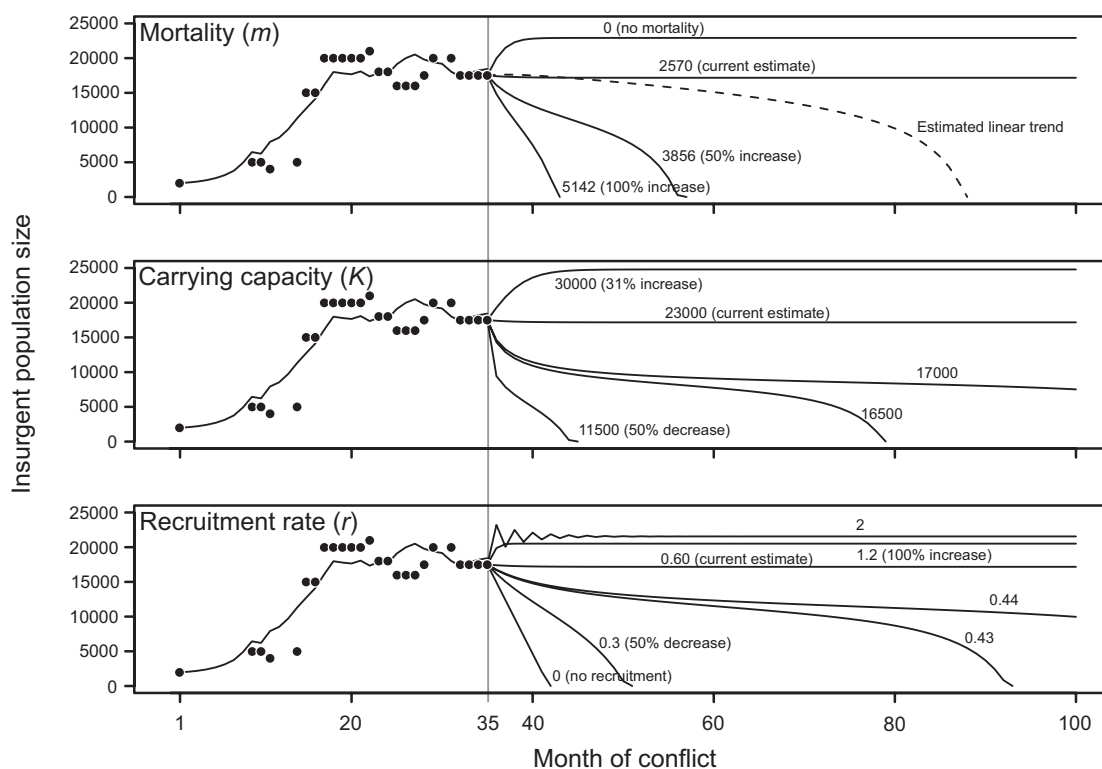
Figure 2. *Logistic models (black lines) fitted to data (black dots) on the size of the insurgency in Iraq, 2003-2006. Multiple lines after month 35 show model predictions under alternative parameter values (one parameter per panel, in which all other parameters are held constant).*

Perhaps the key insight of the Iraq model was that a *combined* change in key parameters (that is, changing two or more of: mortality, carrying capacity, and recruitment) could bring the war to an end disproportionately faster than a change in any one of those parameters alone. It did not escape our attention that the "surge" strategy of 2007—which was a kind of blitz of increased

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military operations, denial of support and safe havens, and counter-insurgency efforts at providing security for the civilian population—did appear to turn the war around. We should not pay too much attention to model predictions about exact timings, but the general effect of the "surge" was concordant with the model. This post-hoc analysis of how predictions of earlier models performed is a key goal of the current project—an examination of the validity of such models given subsequent historical events.

Application to Afghanistan

A basic goal of the grant is to apply these logistic population models to Afghanistan. However, we also want to develop the approach in three ways: (1) think through the broad *qualitative* insights of these population models, which are not beholden to scant or unreliable data; (2) explore the pros and cons of alternative types of population models; and (3) identify better data. These three extensions form the main following subsections of this report.

Before moving on to those, however, Figure 3 below gives a rough idea of what the number of Taliban fighters in Afghanistan might have been over time. This is just for comparison with the data presented above for Malaya and Iraq, but is compiled from various sources and is not thought to be particularly accurate. We are currently trying to identify better, or even proxy, data before fitting models (most data we have come across is considered unreliable).
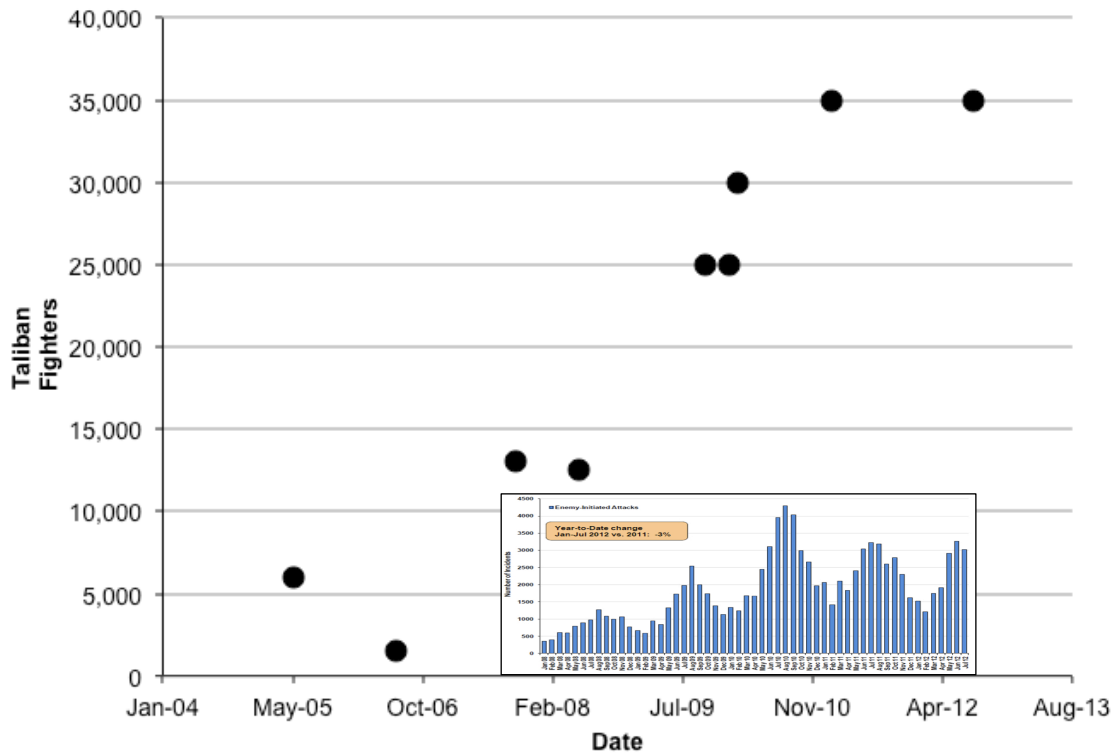
Figure 3. Some estimates of the number of Taliban fighters in Afghanistan, 2004-2012 (compiled from various sources, with means used where a range was given). None of these are considered very reliable. However, note that the pattern of growth here is roughly logistic, as in Malaya and Iraq. The inset blue bar graph is ISAF data on monthly "enemy initiated attacks" from 2008-2012. I have superimposed these here to show that the general trend in number of attacks (discounting seasonal cycles) correlates roughly with the general increase in estimates of the number of Taliban fighters.

Qualitative Insights of Logistic Models

Logistic models generate potentially useful quantitative predictions, but the accuracy and applicability of such numerical predictions may be limited. For example, a range of other factors, not explicitly incorporated into such models, may also influence outcomes. However, part of the utility of logistic models is that they offer *qualitative* as well as quantitative insights—that is, general patterns in how populations tend to change over time depending on key parameters (and irrespective of the precise data or setting). The most important of these is the long-term behavior of populations, which can be radically different depending on its rate of growth (Figure 4).
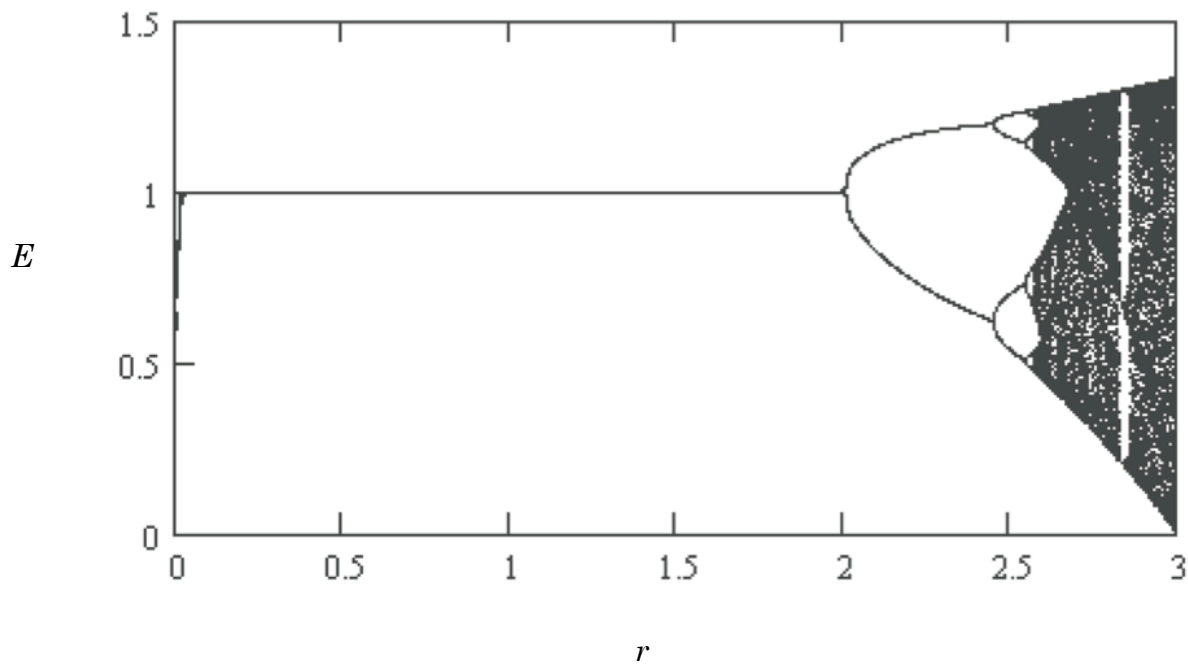
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Figure 4. *As the value of the recruitment rate (r) increases, there is a regular pattern in the equilibrium size (E) of the population (y-axis; here given as a proportion of the equilibrium population size where E = 1). As r increases above 2, population sizes begin to cycle and thereafter become chaotic (Open University 2010).*

Previous research in mathematics and biology has established recurrent patterns of behavior given different values of the recruitment rate *r* (see Table 1).[4] With low values of *r*, over time the population tends to a single, stable, equilibrium population size (*E* = 1). As *r* increases, however, one enters a region in which the population size cycles between two values (represented by the bifurcation at *r* = 2 in Figure 4). As *r* increases further, the population cycles between 4 states. As *r* becomes larger still, there is a great density of possible population sizes, and this means that the population can take on any size, within certain limits. **This is chaotic behavior, and the size of the population cannot be predicted, even if the data are good**.

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[4] May, R.M. (1976) Simple mathematical models with very complicated dynamics. *Nature* 261:459-467.

Table 1. *Long-term behavior of populations in logistic models, depending on recruitment rate r, in terms of E (equilibrium population size, or "carrying capacity"). These are standard results for logistic models (Open University 2010).*

r	Long-term behavior of population
$0 < r \leq 1$	Settles close to E, with values always just below E
$1 < r \leq 2$	Settles close to E, values alternating above and below E
$2 < r \leq 2.44$	2-cycle, with one value above E and one value below E
$2.45 \leq r \leq 2.54$	4-cycle, with two values above E and two values below E
$2.6 \leq r \leq 3$	Chaotic variation between bounds (with some exceptions)

This insight may be important for understanding insurgency. If the population follows a logistic growth model (and it may or may not in any given case), then the insurgent population size over time may have little to do with politics or strategy. For example, we may observe a decline in the insurgent population suggesting that it is losing. However, these changes may simply be the result of the population experiencing cyclical or chaotic dynamics, independent of external factors. An important qualitative insight of logistic models, therefore, is that even excellent data on insurgent population sizes may mislead us about positive or negative trends.[5]

This may be important in itself. However, it also suggests implications for strategy. Imagine a case in which $r < 2$, such that the population may settle at some equilibrium. But then, a strong external pressure (e.g. a US invasion) creates a temporary power vacuum or provokes a spike of support for the insurgency, such that suddenly a large number of people join the insurgency, inflating the value of r. If r increases above 2.6, then **the insurgent population size may undergo wild fluctuations irrespective of COIN strategy**. Worse, the COIN strategy may be effective in principle, but has no apparent correlation with the size or activity of the insurgency, leading to a public relations disaster at home or in the war zone.

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[5] This is not a problem in the Malaya and Iraq models above, because the recruitment rate was estimated to be 1.2 and 0.6, respectively. Those values of r fall well within the range of a single equilibrium population size.

Alternative Models

In addition to insights from logistic population models, another goal of the project is to explore a range of other models developed in ecology, which may provide useful alternative models for the study of irregular warfare.

Ricker Model

One criticism of the logistic model is that it predicts a sudden death of a population whose size exceeds E $(1 + 1 / r)$, a level which generally represents excessive overcrowding. At this size, logistic models predict the extinction of a population within a single time period. The Ricker Model was developed to alleviate this problem.[6] We have not used this model because in our models the insurgent population is unlikely to reach the level of E $(1 + 1 / r)$. In specific locations and sub-populations, however, the Ricker model may be of importance.

Predator-Prey and Competition Models

The logistic models outlined above focus on explaining the insurgent population size alone. However, one could model the insurgent and counter-insurgent forces together, treating them as interacting populations.[7] Such models may include predator-prey models, where the insurgents are treated as "prey" and the counter-insurgents as "predators". As has been noted in ecology, the dynamics of such interactions can be interesting and unexpected, leading, for example, to large oscillations over time with a time lag between the populations. Another possibility is using competition models, where both populations are treated as equals competing over a given resource (which may be represented as territory, population centers, material resources and so on). In collaboration with Jason Lyall and Josh Madin, we are applying these alternative models to the insurgency in Chechnya (1999-2008), where

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[6] A useful review of many of the models outlined here is given in Turchin, P. (2003) *Complex Population Dynamics: A Theoretical/Empirical Synthesis*. Princeton University Press, Princeton.

[7] Turchin, P. (2003) *Complex Population Dynamics: A Theoretical/Empirical Synthesis*. Princeton University Press, Princeton.

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there is better data than Afghanistan.[8] This work is currently in progress. As with the Malaya conflict, Chechnya offers the opportunity to test and validate the approach historically, as well as being an important comparative insurgency to glean lessons for Afghanistan.

Matrix Models

A general criticism of any estimate of insurgent population sizes, let alone models using these data, is that they may include multiple sub-groups. For example, there are full-time and part-time Taliban fighters in Afghanistan, other armed groups, and a dynamic of younger generations growing up and joining the Taliban's ranks. It may be useful to model the growth of (and interaction between) different such sub-groups simultaneously. One method of doing this is with matrix models, which incorporate changes in and between sub-group populations as well as the overall total population. One particular use of this might be to build the Afghan population as a whole into models of the insurgency. With such a long war, an important dynamic may be demographic trends. Is there an increasing or decreasing proportion of young adults available and susceptible to joining the insurgency? This is a very basic question that should be looked at and may have implications for the long-term capacity and persistence of the insurgency.

Complex Adaptive Systems

A popular new approach to analyzing social systems is to treat them as Complex Adaptive Systems (CAS).[9] Various authors have proposed applying this approach to military contexts.[10] My collaborator and graduate student Sara Usher wrote her MSc thesis on integrating CAS with system dynamics (SD). While both approaches are based on systems and complexity theory, the

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[8] See, for example, Lyall, J. (2010) Are co-ethnics more effective counter-insurgents? Evidence from the Second Chechen War. *American Political Science Review* 104:1-20.

[9] Miller, J.H. and Page, S.E. (2007) *Complex Adaptive Systems: An Introduction to Computational Models of Social Life*. Princeton University Press, Princeton, NJ.

[10] Jobbágy, Z. (2007) Developing Strategy: On Effects-Based Operations, Complex Adaptive Systems, and the Importance of Biological Connotations. *Militaire Spectator* 176:251-259.

Moffat, J., Bathe, M., and Frewer, L. (Forthcoming) Complex Adaptive Modelling of Complex Conflict. *Journal of Simulation*.

systems dynamics approach was interesting because it allowed for qualitative inputs in developing the model. Thus, one could examine a case study of interest in detail, such as the insurgency in Afghanistan, and build a plausible model based on factors that are known or thought to be important, based on experience. The rationale for integrating SD and CAS is to account specifically for the processes of interaction and interdependence between actors and processes. This approach is also interesting because it provides a methodological bridge between researchers who prefer to use quantitative methods and those who prefer qualitative methods, such as case studies. Both approaches inform modeling with SD and CAS.

Metacommunity Theory

One obvious criticism of our logistic models is that they lump the entire insurgent population size into a single figure for the whole country. They model the size of the total insurgent population. This ignores any regional variations and distinct sub-populations of insurgent groups. It may therefore be useful to model these, and their interactions, separately. Ecologists have been using this approach for some time in the form of meta-population models. These construct models of multiple small populations, each with its own dynamics but also connected by the migration of individuals between each sub-population.

One newly developing version of this approach is the "metacommunity".[11] The key idea of these models is to capture feedback between the micro- and macro-levels of a population. The approach might be useful for insurgencies because the concepts map on to important features of modern irregular warfare. For example, small-scale behaviors are increasingly thought to underlie emergent dynamics of an insurgency.[12] Metacommunity models also allow flexibility in what exactly they model. Predator-prey versions of these models, for example, can be used to study competition between multiple groups such as the Afghan military, the

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[11] Logue, J.B., Mouquet, N., Peter, H., and Hillebrand, H. (2011) Empirical approaches to metacommunities: a review and comparison with theory. *Trends in Ecology & Evolution* 26:482-491.

[12] Bohorquez, J., Gourley, S., Dixon, A., Spagat, M., and Johnson, N. (2009) Common ecology quantifies human insurgency. *Nature* 462:911-914.

Evans, R. (2012) The micro-level of civil war: the case of central Helmand province. *CTC Sentinel* 5:14-17.

Taliban, warlords, Al Qaeda, ISAF and so on. Such models may be useful for informing alternative possible strategies as well as fitting data.

Metacommunity theory may be especially suited to modeling the insurgency in Afghanistan given porous borders, lack of strong central government, multiple factions, and external groups such as the US and Pakistani military.[13] The principles of metcommunity theory can be implemented in practical terms as an ABM, for example.

Critical Transitions Theory

Finally, my PhD student Sara Usher is currently exploring the utility of "critical transitions theory" as a new way of understanding insurgency. The point of critical transitions theory is that many natural phenomena experience periods of relative stasis, but then apparently without warning can suddenly undergo a major change or "tipping point". Applied to our area of interest a small uprising can suddenly expand into a major conflict or rebellion. Such a change is called a "critical transition".[14] As developed in ecology, these may represent sudden, long-term changes when some threshold is crossed in complex ecosystems. The basic idea is that a set of underlying properties may align to shift the system into an alternative state, and it may not be possible to undo all those individual shifts to return the situation to how it was previously. Thus, there can be a ratchet effect whereby a critical transition takes us into a new territory, and there is no going back.

This may seem a pessimistic perspective because (a) critical transitions have often been thought to be totally unpredictable and (b) once a transition occurs, it cannot be reversed (like, for example, aspects of climate change). However, part of the excitement about critical transitions theory is that it may, in fact, offer insights for predicting when a transition is about to happen. This is possible because in various systems there is a process of "critical slowing down", detectable in data (because the system increasingly fails to

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[13] Johnson, R. (2011) *The Afghan Way of War: How and Why They Fight*. Oxford.
[14] Scheffer, M. (2009) *Critical Transitions in Nature and Society*. Princeton University Press, Princeton, NJ.

recover from the accumulation of small perturbations), which heralds a transition change.[15]

How does this apply to insurgency? Critical transitions may describe various features of insurgency. For example, changes from small scale protests or attacks to full-scale insurgencies and state collapse. The success or failure of COIN efforts once insurgencies are underway may also feature, or face, critical transitions in how the combination of military, economic, political and development strategies come together to cause or obstruct change. As a final example, the development, spread, and decline in specific strategies or technologies such as IED attacks may be useful examined as critical transitions.

The idea here is that there may be emergent properties of insurgencies which make them very hard to predict in a linear fashion. Critical transitions theory offers a way to organize, identify and utilize this knowledge.

Alternative Data

The models above offer various potential insights for understanding insurgency and improving counter-insurgency. Even if we have no data at all, *qualitative* insights about how populations change over time under different circumstances can be important for understanding the dynamics of insurgencies, the efficacy of different COIN strategies, and key parameters of importance.

Where we do have data, we can do more than this, because we can fit a variety of alternative models to the real-world data and test which models make the best (i.e., validated) predictions. One reason we have focused on logistic population models is because they involve only 4 parameters. One only needs estimates of insurgent population size and mortality rates to fit the model. The model will then generate estimates of the two other variables, recruitment rate and carrying capacity. For historical insurgencies such as Malaya this can be informative. Especially if enemy data on their own force strengths are available (as in Malaya and Vietnam), these may represent

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[15] Scheffer, M., Carpenter, S.R., Lenton, T.M., Bascompte, J., Brock, W., Dakos, V., van de Koppel, J., van de Leemput, I.A., Levin, S.A., van Nes, E.H., Pascual, M., and Vandermeer, J. (2012) Anticipating Critical Transitions. *Science* 338:344-348.

reasonable estimates of the insurgent population size which can then be compared against the models.

The problem, of course, is that we often do not have good data—especially for ongoing conflicts where the need is most urgent but the data is worst. Even where such data on insurgent population sizes do exist, they are widely debated and controversial (such as the preliminary data on Afghanistan in Figure 3). Often, they amount to guesses.

We have been exploring solutions to this problem. It is important to rethink what we want to know. We want to know how insurgencies end. We are therefore naturally drawn to estimates of insurgent population sizes because of the implicit assumption that defeating an insurgency is related to defeating all or most of the individuals that make up the insurgency. In fact, however, this is not necessarily the case. The more important factor in the persistence and success of insurgencies can be the extent of insurgent *activity*, not its population size. We are therefore working on identifying proxy variables that track the level of intensity of the insurgency over time (which probably but not necessarily correlate with insurgent population size, as suggested in Figure 3 with the inset data on "enemy initiated attacks"). Here, we find ourselves with much better options for data. The question becomes one of carefully interpreting these proxy data within the context of *population* models. For example, what does the recruitment rate represent? In this case, it may represent the replication of information or strategies, rather than individuals.

Conclusions and Next Steps

There is much work to do, given the multiplicity of alternative models and numerous asymmetric conflicts (both past and present) that can be studied. We believe that ecological models of irregular warfare are well worth pursuing because they draw on well-established theory to generate novel insights and new ways of thinking about the problem, even if these are sometimes qualitative rather than quantitative inferences. But they can also be used to generate quantitative predictions, and these can be tested against data and compared with rival models. Furthermore, we have not come across existing models from other fields or organizations which address the same set of questions about the growth, size and decline of insurgent populations as a whole.

Our primary focus has been on identifying useful models to apply to Afghanistan, given its contemporary importance. Frustratingly, however, this conflict appears to have some of the poorest data—perhaps in part because of political nervousness about advertising estimates of enemy strengths after early optimism in Iraq, as well as the many other obstacles to collating good data such as the terrain, porous borders, multiple opposition groups, and the mixing of civilians and insurgents in Afghan society. However, a new approach of using proxy data (such as the number of attacks, rather than estimates of the population size) may yield useful outcomes. The results of these efforts will be presented in the final report.

Acknowledgements

Natural Security:

3.5 Billion Years of Adapting to Novel Threats

International security, once the domain of nation states, is increasingly dominated by threats from non-state actors. Here, biologist turned political scientist **Dominic Johnson** explains how evolutionary theory can help us to understand – and adapt to – fresh security challenges.

Corbis

Despite the overwhelming military power of NATO, in Afghanistan the Taliban can often appear one step ahead

The theory and practice of international security has traditionally been dominated by the interactions of clearly defined nation states, focusing on strategy and military power. In stark contrast, international security in the 21st century is characterised by a range of novel threats from non-state actors, including terrorism, insurgency, ethnic violence, the proliferation

Military and political commentators have highlighted the growing importance of adaptation in counter-terrorism campaigns

of weapons of mass destruction (WMD), cyber attacks, natural disasters, pandemic diseases and climate change.

We lack a unifying theoretical framework with which to study or address these threats. Though diverse, they share some common features – not least that they are rapidly changing and demand swift responses. In this article I argue that a powerful framework for

Counter-insurgency efforts, such as those in Iraq (pictured), exemplify the new security landscape. Press Association

studying all such rapidly changing threats is provided by evolution: the study of how organisms change and interact with their environment over time.

New Security Landscape

The new security landscape has perhaps been most strikingly exemplified by the counter-terrorism and counter-insurgency efforts in Iraq and Afghanistan. General Anthony Zinni, former commander of US forces in the Middle East, identified the key problem as a failure to *adapt*. As he observed early on in the Iraq conflict: 'This is the first war where we've faced an enemy that's adapted better than we have at a tactical and operational level. We had IEDs [improvised explosive devices] from day 1. … What have we done to adapt? Nothing.'

Many other military and political commentators also highlighted the growing importance of adaptation in counter-insurgency and counter-terrorism campaigns around the world, notably John Nagl, David Kilcullen, General David Petraeus and US Secretary of Defense Robert Gates, who remarked at a congressional hearing in March 2007 that 'as soon as we … find one way of trying to thwart their efforts, [the insurgents] find a technology or a new way of going about their business'. As insurgent and terrorist tactics, organisational methods, and weapons adapt and spread over time, the failure to counter-adapt to deal with them is measured every day in lives.

Although numerous factors are important in understanding counter-insurgency and counter-terrorism – not least political, economic and social ones – a strong sense has developed that the efforts in Iraq and Afghanistan have become primarily wars of adaptation. And adaptation is a great leveller: despite the overwhelming military power of the US in Iraq or NATO in Afghanistan, insurgents often appear to stay one step ahead, reminiscent of the Red Queen in *Through the Looking Glass* – Alice finds that however fast she runs, she always stays in the same place. If adaptation has become so important, where can we turn to find models and tools to study and improve it?

The Natural Security Project

In 2005 marine biologist Rafe Sagarin had the simple but powerful idea of asking whether we can draw lessons from the 3.5 billion year history of life on Earth for improving homeland and international security. Teaming up with the founder of IISS in Washington, DC and former UN weapons inspector, Terry Taylor, the 'Natural Security' project was born, exploring if and how we can derive insights from nature to help tackle problems of international security in the 21st century (Sagarin & Taylor, 2008; Sagarin et al., 2010).

While unpredictable and rapidly changing threats from diverse actors may seem a novelty in the realm of security today, they have been a recurrent challenge

for biological organisms since the dawn of life. Since then, around 100 million species have evolved (and many millions gone extinct), all of which faced lethal threats to their security – such as competition, conflict, predation, resource scarcity, extreme environments and natural disasters. Evolution has responded with a stunning array of (billions of) adaptations for survival and reproduction. These adaptations include both physiological and behavioral strategies ranging from armour and immunity to complex nervous systems and remarkable organisational behavior.

Of course, interactions among biological organisms have many differences when compared to interactions among humans in the modern world. However, there are also many similarities. The guiding idea is that 3.5 billion years of life on Earth reveals fundamental behavioural, organisational and mathematical patterns that underlie competition and conflict – including among humans. The Natural Security project seeks to identify, explore and test these patterns in contemporary conflicts, as well as developing ways to improve strategic decision-making and combat effectiveness.

The project involves an interdisciplinary team of collaborators in Europe and the United States representing the diverse disciplines of anthropology, animal behavior, biology, ecology, evolution, paleontology and psychology, as well as engaging with a range of political scientists, policy professionals and practitioners. My own role in the project, as a biologist turned political scientist, has been to draw on evolutionary principles to explore adaptive behavior in decision-making and conflict.

From Insurgency to International Relations Theory

The project so far has focused on the pressing problems of operational adaptation. However, our current and future work extends evolutionary principles to the level of grand strategy and international politics. The way states interact with each other in the international system

has many differences, but also many parallels, with interacting organisms. One can therefore rethink international relations theory as an evolutionary arena in which state power, strategy and ideology are not just consequences of social, economic or political factors, but also the result of a process of evolutionary selection over long time periods. This may give rise to some unexpected results: for example, work from our group explored evolutionary lessons for when and how we should transmit signals to other actors (Blumstein et al., 2012), and the conditions under which actors that overestimate their capabilities may outcompete unbiased ones (Johnson & Fowler, 2011).

Evolution may seem to be too simplistic a paradigm to apply to the complex world of international relations, especially multifaceted issues

3.5 billion years of life on Earth reveals fundamental behavioural, organisational and mathematical patterns that underlie competition and conflict – including among humans

such as human conflict. However, its simplicity is its power. Natural systems are incredibly complex as well, if not more so, and yet evolution provides the fundamental laws that generate and govern them. The power of evolution is being increasingly recognised in other fields, such as evolutionary game theory in economics and mathematical ecology in global finance. It is also worth noting that simple theories have often had the greatest impact in academic disciplines – not least in international relations. Neorealism, for example, is an incredibly simplistic theory and yet has had a deeper impact on the discipline than perhaps any other. As H. Allen Orr noted, 'Darwinism was revolutionary not because it made arcane claims about biology but because it suggested that nature's underlying logic might be surprisingly simple'.

Applying Evolution to Security

So how might the principles of evolution lend insight into modern security threats? First, humans are biological organisms themselves, so our evolutionary history is essential to our understanding of human physiology, psychology and behavior – especially to explain 'mismatches' where evolved mechanisms cause costly behaviour in modern environments. For this reason, a new and expanding area of research on international security has begun to focus on the role of human biology, with exciting new experimental and empirical research on how human judgment and decision-making is influenced by genetics, endocrinology, neuroscience and psychology (see Anthony Lopez's blog, Evolutionary Politics). Within our own group, we have explored the evolutionary psychology of terrorism and the role of cognitive biases in the way we react (or fail to react) to novel security threats (Sagarin & Taylor, 2008; Sagarin et al., 2010).

Second, the power of Darwin's theory is that the *process* of adaptation by natural selection can apply to any interacting agents, biological or not. Natural selection occurs whenever there are three simple features in place:

• variation in characteristics
• selection of some characteristics over others
• replication of surviving characteristics.

Such features are present in a wide variety of domains, including competition among states, firms, machines and ideas, as well as among individuals.

The wide applicability of natural selection is already utilised in, for example, engineering and

organisational design. Darwinian 'genetic algorithms' are used by engineers to design ship hulls, because testing many thousands of variations in an evolutionary process of trial and error can lead to better designs than a human designer. Our group has explored the implications of evolutionary selection effects for security. For example, an evolutionary perspective suggests that, counterintuitively, *smaller and weaker* sides in a conflict (such as terrorists and insurgents) may actually enjoy an advantage: by being under stronger selection pressure, they are able to adapt faster than the conventional forces opposing them (Johnson, 2009). This may help to explain the vexing problem of poor adaptation identified by General Zinni and Secretary Gates.

A third powerful way in which nature offers lessons for security derives from the principles of ecology. The way that organisms interact with each other and their environment generates hugely entangled ecosystems that are in constant flux. Yet despite the complexity and multiple interacting factors, there are fundamental biological principles at work that allow us to understand and predict patterns of change. Our group has pioneered the use of simple ecological models to track the insurgency in Iraq; they require few variables as inputs but can generate forecasts of future trends and estimate tricky variables such as recruitment rates (Sagarin & Taylor, 2008; Sagarin et al., 2010). Other recent work has identified common ecological patterns that recur among insurgencies from entirely different regions around the world (Bohorquez et al., 2009).

The Future of Evolution

A common criticism that we encounter is that evolution is just an analogy: human interactions may look Darwinian at times, but are actually fundamentally different. However, biology offers a range of hypotheses and tools that allow us to empirically *test* these ideas and compare them with the performance of alternative models. Thus, rather than arguing about the utility of the approach, we can go out and test it with data.

Evolution is not expected to apply to every aspect of human affairs, and will not always offer any (or any practicable) solutions to the challenges of the 21st century. But the idea behind the Natural Security project is to explore what many or few lessons there are in the 'open access library' of 100 million or so species alive today, and the 3.5 billion years of the evolution of life on Earth before that. Evolution offers a vast natural experiment in competition, conflict and security, and has come up with a stunning array of solutions that we ignore (or do not investigate) at our peril.

Evolution offers a vast natural experiment in competition, conflict and security

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